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MESHING HELICAL ROTORS

[1] This application claims the benefit of the filing date of provisional application 60/433,720, having a filing date of Dec. 16, 2003.

BACKGROUND OF THE INVENTION

[2] Screw compressors and expanders are composed of meshing screw or helical rotors. As in the case of gears, screw rotors have pitch circles which represent locations of equal tangential velocity for conjugate pairs of rotors. ~~The~~ These spiral grooves in the rotors are the locations of the volumes of gas which are trapped and in the case of compressors, compressed due to the coaction of a conjugate pair of rotors and an enclosing casing. Accordingly, the volumes of the spiral grooves are a major design consideration, and their width, depth, length and number ~~being~~ are important design variables. The shape of ~~the~~ a cross section of the spiral grooves includes the variables of width and depth, as well as the shape requirements for the driving/driven coaction between the conjugate pair of rotors. Additionally, the conjugate pair of rotors must meet the sealing requirements as the line contact advances along the rotor profile in the driving/driven coaction and as the rotor tips and end faces coact with the enclosing casing. ~~This~~ The line contact follows the perimeters of the rotor profiles and is therefore at a varying tangential speed and has significant radial components. Additionally, the shape and the cross section of the spiral grooves must meet requirements for ease of manufacture and cutting tool life. One problem associated with conventional screw rotor designs is that rotor profiles have generally been designed using a point generated and or circular profiles. These types of profiles are generally more difficult to machine, as well as exposing the rotors to more significant impact with respect to seal line length, drive band contact stress, service life, and sensitivity to temperature fluctuations.

[3] There exists a need therefore for a screw rotor profile for reducing seal line length, reducing contact stress, increasing service life, and exhibiting more flexibility to temperature fluctuation.

SUMMARY OF THE INVENTION

[4] It is an object of this invention to increase the efficiency and longevity of a screw machine.

[5] It is another object of this invention to provide ~~a~~ screw rotor profiles having a reduced blow-hole area for improved efficiency.

[6] It is yet another object of this invention to provide improved rotor tip curves which are less sensitive to tip clearance modification and which can be used for tapered rotors.

[7] It is a further object of this invention to achieve the disclosed performance based objects while improving the manufacturability of the screw rotor profiles.

[8] Another object of this invention is to reduce the contact stress between the male rotor and the female ~~rotors~~ rotor of a screw machine.

[9] These objects, and others as will become apparent hereinafter, are accomplished by the present invention. The present invention provides~~,~~ a conjugate pair of intermeshing rotors ~~having~~ including helical lobes having helical crests and intervening grooves ~~and~~ that are adapted for rotation about parallel axes within a working space of a screw rotor machine. Each rotor has a tip circle, a pitch circle, and a root circle. One~~, one~~ rotor ~~of each pair being~~ is a female rotor formed such that ~~the~~ a major portion of each lobe of ~~said~~the female rotor is located inside the pitch circle of the female rotor. The other rotor is a male rotor formed such that ~~the~~ a major portion of each lobe of ~~said~~the male rotor is located outside ~~said~~the pitch circle of the male rotor. The lobes of one rotor follow the grooves of the other rotor to form a continuous sealing line between ~~said~~the pair of rotors. Each~~, each~~ of the lobes ~~having~~ have a primary flank portion and a secondary flank portion. The~~, wherein the~~ primary flank portion of ~~said~~the lobes of the female rotor have a profile formed from at least one ellipse, and the primary flank portion of the lobes of the male rotor have a profile formed from at least one ~~ellipses~~ellipse.

BRIEF DESCRIPTION OF THE DRAWINGS

[10] For a fuller understanding of the present invention, reference should now be made to the following detailed description thereof taken in conjunction with the accompanying drawing wherein:

[11] ~~FIG.~~Figure 1 is a simplified transverse section through ~~the~~ rotors of a screw machine employing the present invention; and~~.~~

[12] Figure~~FIG.~~ 2 is a simplified view of ~~the~~ a blow hole of the present invention as compared to the prior art.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In ~~the FIG.~~Figure 1, the numeral 10 generally indicates a screw machine, such as a screw compressor or an expander. The screw~~Screw~~ machine 10 ~~has~~ includes a casing 12 with overlapping bores 12-~~1~~a and 12-~~2~~b located therein. ~~Female~~ A female rotor 14 has a pitch circle~~,~~ P_F~~,~~ and is located in the bore 12-~~1~~a. ~~Male~~ A male rotor 16 has a pitch circle~~,~~ P_M~~,~~ and is located in the bore 12-~~2~~b. The axes indicated by points A and B are perpendicular to ~~the~~ a plane of ~~FIG.~~Figure 1 and are parallel to each other. The axes A and B ~~and~~ are separated by a distance equal to ~~the~~ a sum of ~~the~~ a radius~~,~~ R_F~~,~~ of the pitch circle~~,~~ P_F~~,~~ of the female rotor 14 and ~~the~~ a radius~~,~~ R_M~~,~~ of the pitch circle~~,~~ P_M~~,~~ of the male rotor 16. The axis indicated by point A is the axis of rotation of the female rotor 14 and ~~the~~ a center of the bore 12-~~1~~a whose diameter generally corresponds to ~~the~~ a diameter of the tip circle~~,~~ T_F~~,~~ of the female rotor 14. Similarly, the axis indicated by point B is the axis of rotation of the male rotor 16 and ~~the~~ a center of the bore 12-~~2~~b whose diameter generally corresponds to the diameter of ~~the~~ a tip circle~~,~~ T_M~~,~~ of the male rotor 16.

[13] As illustrated, the female rotor 14 ~~has~~ includes six lobes 14a (lands)~~, 14-1,~~ separated by six grooves~~,~~ 14b~~-2~~, while the male rotor 16 ~~has~~ includes five ~~lands,~~lobes 16-~~1,~~a separated by five grooves 16-~~2~~b.

[14] Accordingly, the rotational speed of the male rotor 16 will be 6/5 or 120% of that of the female rotor 14. Either the female rotor 14 or the male rotor 16 may be connected to a prime mover (not illustrated) and serve as the driving rotor. Other combinations of the number of female and male ~~lands~~ lobes and grooves may also be used.

[15] Generally referring to ~~FIG.~~ Figure 1, the major portions of the rotor profile~~,~~ (that is a leading flank or secondary flank D-B for both the male rotor 16 and the female rotor 14 and ~~rotors,~~ a trailing flank or primary flank A-E for both the male rotor 16 and the female rotor 14)~~rotors~~ of the female rotor 14 and the male rotor~~rotors, 14 and~~ 16~~,~~ of the present invention are different ellipses or are generated by different ellipses, with the tip

or root portions being circular arcs. The leading flanks D-B and the trailing flanks A-E are relative to the rotary direction of the female rotor 14 and the male rotor 16. Therefore, as shown in Figure 1, the female rotor 14 rotates clockwise and the male rotor 16 rotates counter-clockwise. As the female rotor 14 and the male rotor 16 rotate, a fluid is compressed or expanded in a chamber between the female rotor 14 and the male rotor 16. The ellipse allows for a continuously changing curved profile, as opposed to a fixed profile with circular curves, yielding a high radius at the drive band for reduced contact stress on the drive band~~,~~ and a low radius near the rotor tip.

[16] With reference to the ~~FIG.~~Figure 1, ~~the~~ a male rotor tip segment A_M-B_M and ~~the~~ a female rotor root segment A_F-B_F are each circular arcs having their centers at the pitch ~~point~~ points P_M and P_F, respectively. The male rotor tip circle has a tangent contact point with the male tip rotor segment A_M-B_M between the points A_M and B_M. The female rotor ~~bottom~~ root circle with the root diameter of the female rotor 14 has a tangent contact point with the female tip rotor segment A_F-B_F between the points A_F and B_F. The male rotor tip segment A_M-B_M ~~allow~~ allows the male tip to have the traditional seal strips or to have the tapered rotors should they are required.

[17] The leading flanks or secondary flanks D-B of the male rotor 16 and the female rotor 14 include~~rotors have~~ two segments. A convex~~Convex~~ segment B_M-C_M is part of an ellipse, with one of its axis overlapped with a line B_M-P_M and having a common tangent at a point B_M with the male tip rotor segment A_M-B_M. A concave~~Concave~~ or concave-convex segment B_F-C_F is conjugally generated by the ellipse convex segment B_M-C_M. The segment~~Segment~~ B_F-C_F has a common tangent at a point B_F with the circular arc female tip segment A_F-B_F. Points C_M and C_F may be just on or inside or outside the pitch circles P_M and P_F of the male rotor 16 and the female rotor 14,~~rotors~~ respectively. A convex~~Convex~~ segment C_F-D_{1F} is part of an ellipse, with one of its axis overlapped with the radius of the segment D_F-D_{1F} at a point D_F~~, and which~~. The segment C_F-D_{1F} has a common tangent at the point C_F with the segment B_F-C_F and has a common tangent at a point D_{1F} with the circular arc segment D_F-D_{1F}. A concave~~Concave~~ segment C_M-D_{1M} at the male rotor leading flank is conjugally generated by the ellipse convex segment C_F-D_{1F} The segment~~Segment~~ C_M-D_{1M} has a common tangent at the point C_M with the convex

segment B_M-C_M~~;~~ and has a common tangent at a point D_{1M} with a circular arc segment D_M-D_{1M}.

[18] The tip portion of the female rotor 14 and the root portion of the male rotor 16 ~~have~~ include two segments. ~~Segments~~ The segments D_M-D_{1M} and E_M-D_M are the two segments of the root portion of the male rotor 16, and the segments D_F-D_{1F} and E_F-D_F are the two segments of the tip portion of the female rotor 14. The segment D_M-D_{1M} is a concave circular arc with its center on the pitch circle P_M of the male rotor 16, and the segment D_F-D_{1F} is a convex circular arc with its center on the pitch circle P_F of the female rotor 14. The segment E_M-D_M is a convex circular arc with its center at the ~~center~~ axis A of the male rotor 16, and the segment E_F-D_F is a convex circular arc with its center at the ~~center~~ axis B of the female rotor 14. The segment~~Segment~~ D_M-D_{1M} has a common tangent at the point D_M with the segment E_M-D_M, and the segment D_F-D_{1F} has a common tangent at a point D_F with the segment E_F-D_F. The female rotor tip segments allow the female tip to have the traditional seal strips or to have the tapered rotors ~~should~~ if they are required. The male root segments allow the male root to have the traditional seal grooves.

[19] The trailing or primary flanks A-F of the male rotor 16 and the female rotor 14 include~~rotors have~~ two segments. ~~Segments~~ The segments A_M-F_M and F_M-E_M are the two segments of the trailing flank A-F of the male rotor 16, and the segments A_F-F_F and F_F-E_F are the two segments of the trailing flank A-F of the female rotor 14. The convex~~Convex~~ segment A_M-F_M is part of an ellipse, with one of its axis overlapped with a line A_M-P_M and having a common tangent at the point A_M with the male rotor tip segment A_M-B_M. ~~Concave~~ The concave segment A_F-F_F is conjugally generated by the ellipse segment A_M-F_M. ~~Segment~~ The segment A_F-F_F has a common tangent at the point A_F with the circular arc female rotor root segment A_F-B_F. ~~Point~~ The point F_F is inside the pitch circle P_F of the female rotor 14. ~~Convex~~ The convex segment F_F-E_F is part of an ellipse, with one of its axis overlapped with ~~the~~ a radius E_F-~~O_2~~-A at the point E_F~~, and which~~. The segment F_F-E_F has a common tangent at a point F_F with the segment A_F-F_F and has a common tangent at a point E_F with the circular arc segment E_F-D_F. The convex~~Convex~~ concave segment F_M-E_M at the male rotor leading flank D-B is conjugally generated by the ellipse segment F_F-E_F. The segment~~Segment~~ F_M-E_M has a common tangent at the point F_M with the

segment A_M-F_M and has a common tangent at the point E_M with the circular arc segment E_M-D_M .

[20] As illustrated in ~~FIG.~~Figure 2, as a consequence of the above described profile, the area of ~~the~~ a blow hole 20 (shown in solid lines) formed by the tip and leading flank sections of the meshing female rotor 14 and the male rotor 16 ~~rotors,~~ is reduced by its shape being curved and narrower, in comparison to prior art blow holes (shown in dashed lines) formed by non-elliptical profiles, without reducing a height h of the blow hole ~~height~~20. By avoiding reduction in height, reasonable gas torque is maintained from the male rotor 16 to the female rotor 14. As known in the art, the blow hole 20 is a leakage channel which connects the leading and following cavities, and it reduces the total efficiency of helical screw compressor. This design, as described and as shown in ~~FIG.~~Figure 2, has the advantage of increasing performance of the compressor.

[21] As a further consequence of the above described profile, ~~the~~ a contact line length or a seal line length between the male rotor 16 and the female rotor 14 is~~rotors~~ are reduced. Since the seal line is one of the most important leakage channels inside a helical screw compressor, leading to reduction in both the total efficiency and volumetric efficiency, the reduction of the seal line length has the advantage of increasing performance of the compressor.

[22] As an additional consequence of the above described profile, the drive band between the male rotor 16 and the female rotor 14~~rotors~~ experience much lower contact stress. For a male drive screw compressor, if the point B_M of the ellipse segment B_M-C_M is located at the long axis of the ellipse, the radius at the point C_M is much larger than the radius at the point B_M due to the geometrical feature of an ellipse. The drive band is located on the segment B-C and near the point C, and the larger radius results in a larger relative radius, which results in lower contact stress. For a female drive screw compressor, the profile section design of segment F-E also gives the profile the ability to control the contact stress at the drive band.

[23] Although preferred embodiments of the present invention have been illustrated and described, other changes will occur to those skilled in the art. It is therefore intended that the scope of the present invention is to be limited only by the scope of the appended claims.